yard Sound earlier in the strata a mile or two high than at the surface.

A sheet of cold air overran the low, warm, and quiet strata about midday, while the cold air followed at the surface a few hours later, and in these facts we have the exact conditions required to produce the observed powerful convection. Such abnormal cooling of the higher strata is as efficient in producing vertical convectional gradients as a superheating of the surface would be, and the evidence that this was the actual case is so good as to render it a practical proof of this circumstance. The upper strata were cooled suddenly by —12° to —15° F., and this brought showers, the waterspouts, and the thunderstorms in close succession. These were followed later by cooler conditions at the surface, giving a temperature fall from the maximum of the day, 72°, to the minimum, 56.5°, at Vineyard Haven. Under these conditions all the observed facts find so natural and satisfactory an explanation that no further remarks seem to be needed to enforce the theory.

But, it should be noted that this overflow of relatively cold layers of air at a moderate elevation upon the warm surface layers, this forereaching and temporary stratification causes an abnormal system of gradients which produce the vertical currents required to set up the motions that tend to reestablish the normal equilibrium of the atmosphere. This local disturbance of the average gradients, due to the fact that the cold upper air, under certain configurations of the lower currents, is drifted forward upon them, is the *primary cause of most of the phenomena classified as thunderstorms, tornadoes, cyclones, and hurricanes.* In short, all these violent local disturbances of the lower air are largely due to this cause, and this is the true source of the energy expended, though it has been attributed by one school of meterologists to the latent heat of condensation, and by the other school to the eddies established by differential horizontal velocities. These two latter sources of energy need not be excluded from consideration, for they contribute their quota to the total energy of circulation, but the first cause is the abnormal stratification of the air at moderate elevations. Thus the groups of thunderstorms which frequent the southeastern quadrants of the cyclone are due to the overflowing of the cold northern current upon the warm current from the south. Tornadoes have the same origin and their location shows that they are due to this cause. The cyclone itself is generated by warm currents of air from the Tropics underrunning the cold sheet which rotates above the surface of the earth, in the hemispherical whirl north of latitude 35°.

The reason for the outflow of warm currents from the Tropics has been indicated in the International Cloud Report, chapters 8 and 10; also there will be found in the MONTHLY WEATHER REVIEW for January and February, 1903, and in the preceding papers of this series, further illustrations and remarks on this theory. The West Indian hurricanes in a similar way are produced in the late summer and autumn by the overflow of the cool upper sheet from the North American Continent upon the warm tropical lower strata, because this sheet is then increasing in size with the southward retreat of the sun. The withdrawal of the sun to the south in fact brings the thermal equator of the higher strata toward the geographical equator earlier than that corresponding to the lower strata. Hence, relatively cold air from the temperate zones at considerable heights, begins to overlay the tropical warm and moist lower strata, and this induces the long continued vertical convection, localized in the hurricane vortex, which in its progressive movement may traverse thousands of miles along its parabolic track. The form of the track is due to the influence of the general circulation localized in centers of action, which builds the south Atlantic high area on the ocean and is manifested in the trade winds, so that the hurricanes usually gyrate along the edge of this special configuration.

The power which is expended for days in succession in a hurricane is due to the fact that the wide expanse of the upper cold sheet covers the temperate zones and overlaps the Tropics at moderate heights. As long as this contrast of temperature, due to abnormal stratification, continues, there is a sufficient source of energy in the resulting thermal engine to produce powerful vertical convection currents, and to sustain the most violent hurricanes, in which the vortex has a depth of several miles in a vertical direction. This theory seems to harmonize completely with what is known about the meteorology of the lower air, and to be such a satisfactory escape from the difficulties of (1) the condensation theory and (2) the dynamic eddy theory, which have always encountered both practical and theoretical objections, that we may expect to find confirmation of it in the future development of the mechanics of the atmosphere.

VARIATION IN TEMPERATURE OVER A LIMITED AREA.

By Prof. Willis I. Milham, Ph. D. Dated Williamstown, Mass., August 4, 1906.

I. INTRODUCTION.

The investigation of the variation in temperature over a limited area was continued and completed during the winter of 1905–6, and the present article contains the results of this investigation. The limited area in question is the village of Williamstown, Mass., which is about one and one-half miles long and three-quarters of a mile wide, and is situated on three small knolls in the middle of a larger depression. It consists of detached houses, surrounded by ample lawns and gardens, and has a diversified surface made up of fairly level areas, marked valleys, plenty of running water, and differences of elevation amounting to 120 feet.

One phase of the variation was investigated during the winter of 1904–5 and the results were published in the MONTHLY WEATHER REVIEW for July, 1905, Vol. XXXIII, page 305, under the title: "The variation in minimum temperatures on still, clear nights within the confines of a village". Here may also be found a complete description of the village, together with an accurate topographical map. A brief summary of that investigation will be useful as a preface for the present article. Accurate, self-registering, minimum thermometers of the regular Weather Bureau type were mounted in exactly the same way and exposed at ten different stations in the village. As long as the ground was covered with snow, their readings were noted whenever a decided fall in temperature occurred during the night. The maximum variation noted was 10° F. and the average variation for the thirty-six nights on which observations were taken was 5.1°. It was furthermore found that the variation was much less on a windy night, that it was not influenced by the coldness of the night, and that it was greatest on two different, carefully described types of nights. It was also found that air colder and thus more dense tended to drain into the valleys; but elevation was not the all-determining factor, for the openness of the valley, its direction, the roughness of its surface, and the wind direction also played a part. The regularity with which certain stations were either warmer or colder than other stations was investigated and it was found that one station proved to be quite constantly the coldest and another the warmest in the series of ten.

In order to determine completely the behavior of a limited area as regards variation in temperature, two more questions must be investigated. These questions are: (1) Does any variation in temperature exist during the daytime? (2) Does the variation remain constant during a given night, or does it change and perhaps grow larger as the time of minimum temperature approaches? It is the purpose of this article first to answer these two questions and then to summarize the results and give a complete picture of the behavior of a limited area as regards variation in temperature.

For the investigation of the above questions two stations were chosen, and these were naturally the two which had proved themselves to be the warmest and coldest during the previous investigation. This choice was determined by the consideration that if a variation in temperature over the limited area was to be found, it would certainly show itself between the stations which had been found to be warmest and coldest. These stations have a difference of elevation of 66 feet, the elevation of the thermometer at one being 706.5 and at the other 640.5 feet. In this article these stations will be spoken of as the upper and lower. They correspond exactly to station 8 (warmest) and station 7 (coldest) of the previous investigation. The upper station is located near the top of a knoll and is surrounded by a fairly level field for a few hundred feet on every side. The lower station is at the bottom of a valley, 1700 feet northwest of the upper station. The topographical map referred to above shows in detail the surroundings of these stations.

II. VARIATION IN TEMPERATURE DURING THE DAYTIME.

The daytime temperatures at the two stations were determined by means of an Assmann's ventilated thermometer made by R. Fuess, of Berlin. This instrument is now too well known to need description, and can be relied upon to determine the real air temperature correctly to at least 0.1° F. even in bright sunshine. The observations made on twelve different days during the winter are given in Table 1. Those days in particular were chosen when there was plenty of sunshine and the wind velocity was small. In fact, the table contains observations on every bright, sunny day with small wind velocity as long as the ground was covered with snow. If no variation can be detected on such days, surely none can be expected when the wind velocity is high and the sky is overcast. The first column contains the date and time of observation. The time indicated is always that for the observation at the lower station. The temperature given for the upper station is the mean of two temperatûres taken the same number of minutes before and after the observation at the lower station. These two temperatures never differed by more than a few tenths of a degree at most. The wind velocities given in this table, and all subsequent tables, were determined by a watch-pattern anemometer and also by noting the rapidity of drift of smoke from a chimney, or one's breath, or some light object. The anemometer was calibrated by walking with a known speed both against and with the wind. The absolute values of these wind velocities may be somewhat erroneous, but they will nevertheless serve to indicate the relative windiness at the different times of observation. The ventilated thermometer was held exactly five and one-half feet above the surface of the ground in determining a temperature, and the wind velocity was observed at this same height.

TABLE 1.—*Temperature observations at two stations in Williamstown, Mass., during the daytime.*

Date and time.	Station.		Wind direction and velocity, miles per hour.	Character of the sky.	Depth of snow on ground.	Remarks.
	Upper.	Lower.				
1905.	° *F.*	° *F.*			*Inches.*	
Dec. 1, 2:15 p. m....	23.5	23.5	nw., 5	Cloudless	0	Dry, frozen ground.
Dec. 5, 2:40 p. m....	25.7	26.0	nw., 3	Partly cloudy.	0.3	
Dec. 13, 2:30 p. m..	37.9	37.9	w., 3	Overcast	2.0	Melting snow.
Dec. 16, 3:00 p. m...	24.8	24.8	nw., 1	Cloudless	1.0	
1906.						
Jan. 10, 2:35 p. m...	20.8	20.5	se., 2	Light haze....	3.0	New snow.
Jan. 11, 2:15 p. m...	36.5	36.5	se., 2	Overcast......	3.0	
Feb. 3, 2:50 p. m....	12.6	12.9	n., 3	Cloudless	Trace.	
Feb. 6, 2:40 p. m....	1.3	1.8	nw., 2	Cloudless	1.0	
Feb. 8, 2:40 p. m....	15.8	16.2	nw., 4	Cloudless	1.0	
Feb. 17, 2:15 p. m...	31.8	31.8	nw., 2	Cloudless	13.0	
March 14, 2:45 p. m.	25.0	25.2	nw., 5	Cloudless	Trace.	
March 24, 2:15 p. m.	23.4	24.3	nw., 3	Cloudless	5.0	

It will be seen that the variation is extremely small. The largest value is 0.9° and the average for the twelve days is 0.19°, the lower station being the warmer. If the three days are excluded when there was only a trace of snow upon the ground, the average variation is 0.20°. The higher temperature on the part of the lower station is analogous to what is found on a much larger scale in connection with mountain and valley stations. Wind velocity is much greater during the day than at night, and convection is operative only during the daytime. It would seem that these two processes are sufficient to so thoroughly mix the lower layers of the air that a variation in temperature over a limited area during the daytime is hardly to be detected. In considering the amount of the variation found on these days it must be noted that these are extreme cases. In the first place, the warmest and coldest stations in the limited area were chosen; secondly, those days were chosen when the variation would be largest; and finally, the observations were taken at the most favorable time of day for a variation.

III. VARIATION IN TEMPERATURE DURING THE THREE TYPES OF NIGHTS.

The two thermometers used to determine the temperature during the night and the minimum temperatures were self-registering, minimum, alcohol thermometers of the regular Weather Bureau type. In order to eliminate the possibility of inaccuracies in the thermometers as the cause of the variations noted, the following precautions were taken: (1) The two thermometers were wrapped up together in cloth and placed in a room where the temperature was nearly constant. At the end of several hours the two thermometers indicated the same temperature. This was done at the beginning and end of the experiment and for several different temperatures. (2) The thermometers were read on several different occasions during a high wind while the temperature was nearly stationary, either at night or when the sky was overcast. No difference was found on such occasions. (3) The two thermometers were frequently interchanged.

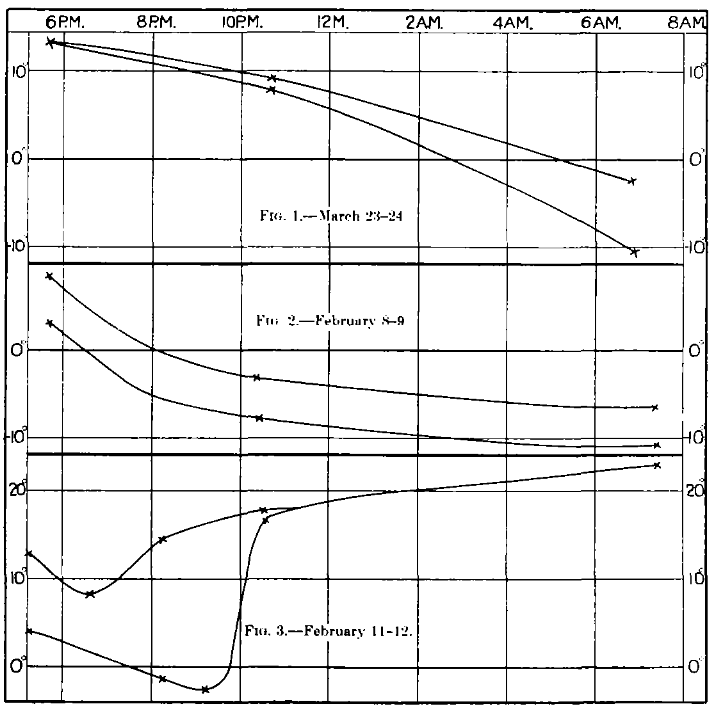
The use of identical thermometers is absolutely essential. Two thermometers of radically different form and construction may indicate the same temperature when wrapped up together in a constant temperature room, and yet when exposed in the open at night they may, in extreme cases, show a difference of even several degrees. The thermometers were mounted on unpainted pine boards about eighteen inches long and seven inches wide, and were exposed in the open, without a shelter of any kind, exactly five and one-half feet from the surface of the ground. They were exposed on the northwest side of small trees, at least twenty-five feet from the nearest building, and with a much larger clear space on the northwest side. Most of the observations were taken over a snow surface. Absolute identity of thermometer, mounting, exposure, and surface can not be emphasized too strongly, for many of the reported variations in temperature over limited areas are due simply to the fact that the thermometers, although accurate, are different, or are mounted and exposed in a different way. These thermometers do not, of course, indicate the real air temperature, even at night when exposed in the open. Owing to radiation their indications may be anywhere from a small fraction of a degree to, in extreme cases, several degrees below (never above) the real air temperature. When two identical instruments are mounted and exposed in the same way, it can be safely assumed that both are affected alike, and read the same amount below the real air temperature.

From December until April there were twenty-one nights during which variations in temperature betwen the two stations occurred. It was found that these nights could be divided into three groups, each with marked characteristics of its own. The observations for the eleven nights of the first type are given in full in Table 2. The first column contains the date and time of observation. The time indicated is always that for the observation at the lower station. The thermometer at the upper station was always read the same number of minutes before and after the observation at the lower station, and the temperature given for the upper station is the mean of these two readings. The method of obtaining the wind velocities was explained above.

Table 2.—*Temperature observations at two stations in Williamstown, Mass., during nights of the first type.*

TYPE I.

Date and time.	Station. Upper.	Station. Lower.	Wind direction and velocity, miles per hour.		Character of the sky.	Depth of snow on ground.	Remarks.
1905.	° F.	° F.				Inches.	
Nov. 30–Dec. 1, 3:33 p.m	17.2	18.0	nw.,	18	Cloudless	0.0	Dry, frozen ground.
5:23 p.m	12.9	12.5	nw.,	16	Cloudless	0.0	
10:32 p.m	9.2	9.0	nw.,	10	Cloudless	0.0	
Min......... ..	6.5	5.3	nw.,	3	Cloudless	0.0	Minimum at sunrise.
1906.							
Feb. 2-3, 5:20 p.m	0.9	1.0	nw.,	15	Cloudless	0.3	
10:00 p.m	− 0.5	0.0	nw.,	10	Cloudless	0.3	Wind gusty.
Min.	− 7.5	− 8.0	nw.,	3	Cloudless	0.3	Minimum at sunrise.
Feb. 5-6, 7:30 p.m	3.3	3.5	nw.,	12	Cloudless	2.0	
10:40 p.m	− 1.8	− 1.5	nw.,	4	Cloudless	2.0	
Min...........	−10.8	−13.7	nw.,	1	Cloudless	2.0	Minimum at sunrise.
Feb. 10-11, 5:30 p.m	20.9	21.0	nw.,	10	Partly cloudy.	11.0	
10:55 p.m	12.0	12.2	nw.,	10	Cloudless	11.0	
Min...........	−10.5	−18.0		0	Cloudless	11.0	Minimum at sunrise.
Feb. 15-16, 5:50 p.m	9.0	9.0	nw.,	12	Overcast	14.0	
8:35 p.m	7.4	7.5	nw.,	4	Overcast	14.0	
10:45 p.m	5.2	5.2	nw.,	3	Overcast	14.0	
Min...........	−10.9	−20.0		0	Cloudless	14.0	Minimum at sunrise.
Feb. 22-23, 5:50 p.m	29.3	29.5	nw.,	12	Cloudless	Trace.	Snow in patches, dirty.
10:36 p.m	24.5	24.5	nw.,	3	Cloudless	Trace.	
Min...........	18.0	14.0	nw.,	1	Cloudless	Trace.	Minimum at sunrise.
Mar. 14-15, 7:10 p.m	18.4	18.0	nw.,	1	Cloudless	Trace.	
10:40 p.m	14.0	13.0	nw.,	½	Cloudless	Trace.	
Min...........	11.9	8.5		0	Overcast	Trace.	Minimum at 3 a.m.
Mar. 17-18, 7:05 p.m	18.0	18.0	nw.,	8	Cloudless	4.0	New snow.
10:50 p.m	15.0	15.0	nw.,	6	Cloudy.........	4.0	
Min...........	7.5	− 1.0		0	Cloudless	4.0	Minimum at sunrise.
Mar. 18-19, 7:40 p.m	20.0	20.0	nw.,	3	Cloudless	3.0	
10:40 p.m	16.0	8.0		0	Cloudless	3.0	
Min...........	7.2	− 2.0		0	Cloudless	3.0	Minimum at sunrise.
Mar. 22-23, 5:50 p.m	17.1	17.0	nw.,	7	Cloudless	6.0	
11:00 p.m	13.0	13.0	nw.,	4	Cloudless	6.0	Wind gusty.
Min...........	7.8	7.7	nw.,	3	Cloudless	6.0	Minimum at sunrise.
Mar. 23-24, 5:40 p.m	**13.0**	**13.0**	**nw.,**	**10**	**Cloudless ......**	**5.0**	
10:35 p.m	**9.0**	**8.0**	**nw.,**	**3**	**Cloudless ... ..**	**5.0**	
Min............	**− 2.9**	**−10.5**		**0**	**Cloudless ......**	**5.0**	**Minimum at sunrise.**



Temperature variations.

The chief characteristics of this type of night are these: Just after sunset the wind would be from the northwest with a fairly large velocity, in one case as high as eighteen miles per hour. The sky would often be cloudless, but sometimes overcast or partly cloudy. During the night the wind would die down and the sky become clearer. By sunrise, or a little before, when the minimum of temperature usually occurred, the wind would be blowing with a velocity of three miles per hour, or less, and the sky would be cloudless. Often the wind would die down to an absolute calm. As long as the wind velocity remained about three miles per hour, or more, the two stations would show but little variation in temperature. The lower station would often be a small fraction of a degree warmer than the upper station. As soon as the wind velocity fell below about three miles per hour, the variation would begin to appear, and would steadily increase with the dying down of the wind until the time of minimum temperature, when the lower station was always much colder than the upper. In one case (March 19) the difference was 9.2°. The night of March 23–24 is a very characteristic night of this first type, and the observations are printed in black-faced type in Table 2. In fig. 1 these observations are plotted to scale and show graphically the behavior of a limited area during this type of night.

The observations for the eight nights of the second type are given in full in Table 3.

Table 3.—*Temperature observations at two stations in Williamstown, Mass., during nights of the second type.*

TYPE II.

Date and time.	Station. Upper.	Station. Lower.	Wind direction and velocity, miles per hour.		Character of the sky.	Depth of snow on ground.	Remarks.
1905.	°F.	°F.				Inches.	
Dec. 1-2, 5:15 p.m	17.8	15.0	se.,	1	Cloudless	0.0	Dry, frozen ground.
10:30 p.m	15.0	13.0	se.,	½	Light haze...	0.0	
Min	14.5	12.5	se.,	½	Light haze...	0.0	Minimum, 12:15 a.m.
1906.							
Jan. 10-11, 5:12 p.m	16.8	11.5	se.,	½	Cloudless	3.0	New snow.
8:25 p.m	12.0	8.0	se.,	¼	Cloudless	3.0	
10:40 p.m	13.3	8.0	se.,	½	Cloudless	3.0	
Min...........	7.9	4.0		0	Light haze....	3.0	Minimum, 6:15 a.m.
Feb. 8-9, 5:45 p.m	**8.3**	**3.0**	**s.,**	**1**	**Cloudless......**	**1.0**	
8:00 p.m	**0.5**	**− 5.5**	**s.,**	**½**	**Cloudless......**	**1.0**	
10:25 p.m	**− 3.1**	**− 8.0**	**s.,**	**¼**	**Cloudless......**	**1.0**	
Min	**− 6.8**	**−11.0**		**0**	**Cloudless .....**	**1.0**	**Minimum at sunrise.**
Feb. 16-17, 5:50 p.m	15.0	5.5		0	Cloudless	14.0	
11:55 p.m	− 1.3	−11.0	se.,	¼	Cloudless	14.0	
Min...........	− 8.8	−17.0		0	Cloudless	14.0	Minimum at sunrise.
Feb. 17-18, 7:10 p.m	14.5	5.0	se.,	¼	Cloudless	13.0	
11:05 p.m	8.8	− 2.0	se.,	1	Cloudless	13.0	
Min...........	6.5	− 3.0	se.,	1	Cloudless	13.0	Minimum at 1 a.m. Stationary temperature until morning.
Mar. 13-14, 7:27 p.m	16.8	15.0	nw.,	½	Hazy	0.5	
10:15 p.m	13.5	11.5	nw.,	½	Light haze	0.5	
Min...........	13.2	11.2	se.,	½	Overcast......	0.5	Minimum at 1 a.m.
Mar. 24-25, 6:05 p.m	20.0	17.0	nw.,	2	Cloudless	5.0	
10:50 p.m	4.3	− 3.0	se.,	¾	Cloudless	5.0	
Min...........	− 6.0	−12.8		0	Cloudless	5.0	Minimum at sunrise.
Mar. 25-26, 7:00 p.m	27.3	22.0		0	Cloudless	3.0	
10:45 p.m	16.0	9.2		0	Cloudless	3.0	
Min...........	12.2	6.0		0	Overcast	3.0	Minimum at sunrise.

The chief characteristics of this type of nights were these: During the whole night from sunset to sunrise the wind velocity was very small. In fact it never exceeded two miles per hour during any one of these eight nights, and it was usually much less than one mile per hour. The wind direction was not uniform, sometimes from the northwest and sometimes from the southeast or south. The sky was usually cloudless, although it sometimes became hazy or overcast before morning. Within an hour after sunset a marked variation in temperature between the two stations was observed, and this variation remained nearly constant during the entire night. The night of February 8–9 is perhaps the most characteristic of this group and the observations have been printed in black-faced type in Table 3 and are plotted to scale in fig. 2.

There were only two nights of the third type during the winter, and the observations for these two are given in full in Table 4.

The change in wind direction is the most characteristic thing about this type of night. In the early evening the wind would be blowing from the northwest with small velocity. It would then die down to a calm in a few hours, change direction to the southeast and increase again in velocity. The minimum of temperature always came early in the night. The night of February 11–12 is a particularly fine example of this type. The observations are printed in black-faced type in Table 4, and fig. 3 shows them plotted to scale. Several things in connection with this night are worthy of notice. The minimum temperature at the upper station occurred about two hours earlier than at the lower station. This means that the increasing southeast wind replaced the air at the upper station with warmer air, and thus caused a rise in temperature two hours before it was able to remove the pocket of cold air from the lower station. The variation in the minimum temperature on this night was the largest of the winter and amounted to 11.5°. This is 1.5° larger than the largest variation noted during the winter of 1904–5. Although the minimum temperatures differed by 11.5°, at 8:10 p. m. there was a difference in temperature of 16.3° between the two stations.

TABLE 4.—*Temperature observations at two stations in Williamstown, Mass., during nights of the third type.*

TYPE III.

Date and time.	Station.		Wind direction and velocity, *miles* per hour.	Character of the sky.	Depth of snow on ground.	Remarks.
	Upper.	Lower.				
1906.	°*F.*	°*F.*			*Inches.*	
Feb. 7–8, 5:45 p.m	− 3.0	− 3.0	nw., 3	Cloudless	1.0	
8:00 p.m	− 6.8	− 6.5	nw., 2	Cloudless	1.0	
Min...........	−11.0	−15.0	nw., 0	Cloudless	1.0	Minimum about 10 p. m. Went steadily up with no variation and increasing wind.
11:40 p.m	− 7.5	− 7.5	se., 2	Overcast	1.0	
Feb. 11–12, 5:10 p.m	**13.0**	**4.0**	**nw., ½**	**Cloudless ......**	**10.0**	
Min	**8.5**	......	....	....	....	**Minimum at upper station.**
8:10 p.m	**14.8**	**− 1.5**	**se., 1**	**Cloudless .....**	**10.0**	
Min	......	**− 3.0**	....	....	....	**Minimum at lower station.**
10:30 p.m	**17.3**	**17.0**	**se., 6**	**Partly cloudy ..**	**10.0**	
Sunrise	**23.0**	**23.0**	....	....	....	

As was stated above, a variation in temperature was detected on twenty-one nights, and the nights have been divided into three groups, each with marked characteristics of its own. During all other nights the wind velocity remained above three miles per hour, and it was often stormy or cloudy in addition. Many observations were made at odd times during such nights, but a variation as large as 1° was never detected. During the early morning following a night when a variation in temperature had existed the lower station would become warmer more rapidly than the upper station, so that within an hour or two after sunrise no appreciable variation could be found. This was frequently tested by means of the ventilated thermometer in the early morning an hour or two after sunrise.

Wind direction and velocity are the distinguishing characteristics of the three types of nights which have just been described. During a night of the first type the wind has a fairly high velocity during the first part of the night; it then dies down to a small velocity or an absolute calm without changing direction. During a night of the second type the wind velocity remains very small during the entire night. During a night of the third type the wind is from one direction, with a small velocity in the early evening; it quickly dies down to a calm, changes to the opposite direction, and increases in velocity again. These facts have been restated here to emphasize the importance of wind velocity. For the limited area under investigation, namely, the village of Williamstown, the critical value of wind velocity seems to be about three miles per hour. As long as wind velocity has a greater value than this no variation of any amount can be found; but as soon as it sinks below this value the variation makes its appearance, and its change during the night depends upon the type of night, or, in other words, depends upon the change in wind direction and velocity during the night. The cause of variation in temperature is the interaction of the wind and the drainage of cooler, and thus more dense, air into the valleys. This drainage of cooler air tends to give the places of less elevation a lower temperature. The wind tends to remove this cooler air and mix it with other masses of air, thus maintaining a uniform temperature over the limited area. The ability of the wind to remove this cooler air depends, apart from its velocity, upon the direction of the valley, the direction of the wind, the openness of the valley, and the roughness of its sides. It will thus be seen that, in general, places of less elevation should have a lower temperature at night, but it will also be seen that elevation is not the all-determining factor. On a topographical map of a limited area which had never been investigated, the warmer and colder stations could probably be located with a fair degree of certainty, but the points could not be arranged in order of coldness depending upon elevation alone.

IV. SUMMARY.

Whenever, in this or the former article, mention has been made of a limited area, the village of Williamstown has been the particular limited area to which reference has always been made. The results which have been obtained by investigating this particular limited area for two winters can, however, be generalized so that the behavior of any limited area as regards variation in temperature can be stated. A limited area, in general, can perhaps be best defined as a square mile of surface roughly in the form of a circle or square. During the daytime, on account of convection and the higher values of wind velocity, no appreciable variation in temperature over a limited area will be found. On some particularly favorable days, namely, those with plenty of sunshine and low wind velocity, the lower stations (particularly those in narrow valleys) may be a few tenths of a degree warmer than the upper stations. At night the existence of a variation will depend almost entirely upon the velocity of the wind. For every limited area there will be a critical value of wind velocity. For all ordinary limited areas it will probably not be far from three miles an hour. As long as the wind velocity remains larger than this, no variation in temperature will be found. As soon as the wind velocity sinks below this critical value a variation will begin to be manifest. The change in this variation during the night will depend upon the type of night, and three types of nights, each with marked characteristics of its own, can be distinguished. These three types of nights have been fully described above. The maximum variation which may be expected for an ordinary limited area is from 10° to 15° F. This, however, might vary considerably with different limited areas. All the stations in a limited area can be arranged in a series representing their relative coldness, the lower or valley stations being the colder, and the upper stations the warmer. This series should be determined by observations, however, as elevation is not the all-determining factor. A good idea of which stations should be the colder can be determined from a topographical map of the area.

V. PRACTICAL CONSIDERATIONS.

All temperature data, such as the normal daily, monthly, and yearly temperature, the different values of range, etc., are now computed from the maximum and minimum temperatures which are observed at the station in question. Suppose that two stations had been established, one at the warmest and another at the coldest point in Williamstown; the normal yearly temperature, for example, at these two stations would show a difference of probably more than a degree, and the values of range would show a difference of several times that amount. The point to emphasize is the effect on climatological data of the choice of a station within a limited area. It is often stated that for climatological data and charts, the results of observations made at cooperative stations of the Weather Bureau, which are usually located in a village or small city, are to be preferred to those made at regular Weather Bureau stations, as these are usually located in large and growing cities. Very little is usually known of the limited area which surrounds a cooperative station, and yet the choice of location in such an area would probably affect the data as much as the presence of a city.

In order to investigate the effect of a city on regular stations and get more accurate climatological data, a substation just outside the city is now often maintained. It would seem that still more valuable information would be gained if the limited area about such a substation were investigated for two or three years and then two stations established, one at the warmest and the other at the coldest point.

MONTHLY REVIEW OF THE PROGRESS OF CLIMATOLOGY THROUGHOUT THE WORLD.

By C. FITZHUGH TALMAN, U. S. Weather Bureau.

CHARTS SHOWING THE DISTRIBUTION OF CLIMATOLOGICAL STATIONS.

Next to a complete climatological dictionary, or compilation of climatic normals for the world, perhaps the greatest desideratum in the way of climatological literature is an atlas and gazetteer of meteorological stations.[1] Charts showing the distribution of stations of all orders are especially desirable, as they enable one to determine exactly, at a glance, at what points on the earth's surface climatological observations are being carried on. Such charts are published by a few, but only a few, of the climatological services of the world, in connection with their periodical reports. (For the United States they are published in the annual summaries of the section reports issued by the Climatological Service of the Weather Bureau.)

With the approval of the Editor of the MONTHLY WEATHER REVIEW the writer intends to include in this column, from month to month, sketch maps showing the location of meteorological stations in various countries, especially those in which meteorological work on an extensive scale has but recently begun. Space will not generally permit lists of the stations to be included, nor any detailed statistics concerning them, but it is hoped that the charts alone will prove an acceptable contribution to climatology. In some cases these charts will be reprints of those that appear in various foreign publications to which but few readers of the REVIEW have access; but more often they will be especially prepared for the REVIEW, on the basis of the most recent information obtainable, by correspondence and otherwise.

We begin the series with the chart accompanying the following note.

A NEW CLIMATOLOGICAL SERVICE IN SICILY.

Following the example of the observatories of Palermo and Catania, which have established numerous thermopluviometric stations in their respective provinces, the observatory of Messina has inaugurated a network of such stations in the province of Messina. Their distribution is shown by the accompanying chart, fig. 1. The greater part of these stations began their observations January 1, 1906, and the results are to be published hereafter in the Annuario of the observatory of Messina.

The director of this service, and of the observatory, is the well-known meteorologist, geophysicist, and astrophysicist, G. B. Rizzo. Since 1904 the observatory has formed a part of the Royal University of Messina.

THE CLIMATOLOGICAL ATLAS OF INDIA.[2]

The appearance of this work has been awaited with general interest by the meteorological world since the publication, in Indian Meteorological Memoirs, vol. 17 (Calcutta, 1904), of the numerical data upon which it is based, accompanied by the announcement that the publication of the atlas had been sanctioned by the government of India. Now that the atlas is before us, we learn that a Handbook of the Meteorology of India is in preparation, which, with the atlas, will form a complete work, each part supplementing the other, and be a record of the more important results of meteorological observation and investigation in India during the period 1876–1900.

The Climatological Atlas of India takes its place beside Hellmann's rainfall volumes for Germany (see July REVIEW, p. 328), as one of the two great contributions to geographical climatology that have appeared so far this year. As to the authoritative character of this work and the excellence of its mechanical execution, it need only be said that its author is Sir John Eliot, the late meteorological reporter to the government of India, and the publishers are Messrs. Bartholomew & Co., who produced the beautiful Bartholomew-Herbertson-Buchan Atlas of Meteorology (Bartholomew's Physical Atlas, vol. 3).

In order to see how much of an advance the new atlas represents in the graphical presentation of Indian climate, the writer has compared the charts of pressure and temperature, respectively, with Buchan's pressure charts of the globe in the Challenger Report (1889, reprinted on a small scale in Bartholomew's Atlas of Meteorology, 1899) and Buchan's isothermal charts for India in Bartholomew's Atlas of Meteorology, plate 9 (based on manuscript maps prepared for the Challenger Report). On the July pressure charts it is noted that the heart of the Asiatic summer "low" lies well up the Indus Valley, instead of along the northern shore of the Arabian Sea, where Buchan puts it. There are many other important readjustments of the isobars, especially in northern India. It is noticed, however, that on the large plates (7–10), showing the distribution of pressure over southern Asia and the Indian Ocean, Buchan's isobars have been copied exactly, except over India itself, so that these plates hardly represent the most recent knowledge of pressure distribution over the Indian monsoon area. The isothermal charts in many places differ strikingly from Buchan's, and show how greatly the latter stood in need of revision in the light of recently accumulated data.

Besides the 120 plates embraced in this work, representing the normal distribution and fluctuations of all the principal meteorological elements over India, there are 32 folio pages of letter-press, containing, among other things, the best brief history of meteorological work in India that has yet appeared

THE FOGS OF RUWENZORI.

That this much talked of mountain baffled the efforts of some of the world's most expert mountaineers to scale its loftier summits until the present summer, when the feat was accomplished by the Duke of the Abruzzi, was not due to the configuration of the mountain, which appears to offer no difficulties not easily surmountable by the ordinary expedients of mountaineering, but to the fog or cloud in which the upper levels are almost constantly enwrapped.

Lieutenant Behrens, R. E., writing on "The snow peaks of Ruwenzori", in the Geographical Journal for July, says:

> Though for nine months in a neighborhood from which, on most days, Ruwenzori might have been visible from my tent, I saw it only seven times, and then only for a few minutes just after sunrise. So

[1] An ideal work of this character would include former stations as well as those now in operation, providing they furnished trustworthy observations for a reasonably long period. (For the latter no absolute limit should be fixed. A station in the heart of Asia represented by six months of observations would be well worth including; whereas in Germany, with its 3000 stations, those having less than two years of observations could very well be ignored, if no longer in operation.) The work would then have a permanent value, regardless of the changes that are constantly taking place in the distribution of stations.

[2] India. Meteorological Department. Climatological Atlas of India, published by the authority of the government of India under the direction of Sir John Eliot. Edinburgh, 1906.